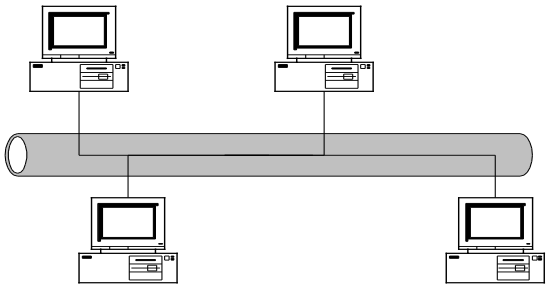
Lect. 5

Multiple Access Techniques

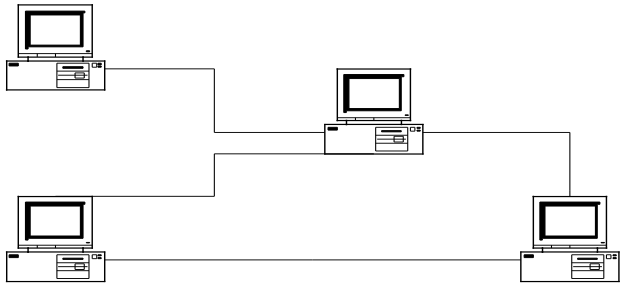
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Types of “Single Segment” Networks

- There are two types of communication networks:
 - Broadcast Networks: All stations share a single communication channel
 - Point-to-Point Networks: Pairs of hosts (or routers) are directly connected



Broadcast Network



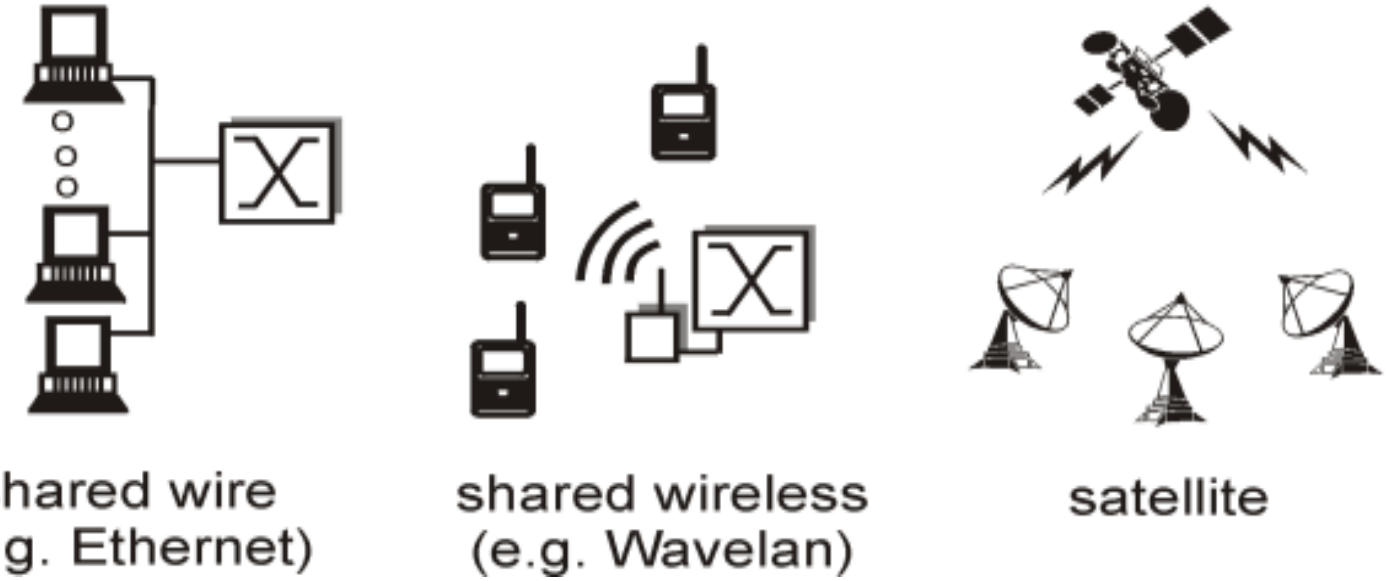
Point-to-Point Network

- Examples of single segment networks:
 - broadcast: Ethernet, WiFi,
 - point to point link: Frame Relay
- Typically, local area networks (LANs) are broadcast and wide area networks (WANs) are point-to-point

Multiple Access

- **Broadcast link** used in LAN consists of multiple sending and receiving nodes connected to or use a single shared link

Broadcast links Examples



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LANs: Data Link Layer - MAC and LLC

- In any broadcast network, the stations must ensure that only one station transmits at a time on the shared communication channel
- The protocol that determines who can transmit on a broadcast channel is called the Medium Access Control (MAC) protocol
- The MAC protocol is implemented in the MAC sublayer which is the lower sublayer of the data link layer
- The MAC is physical layer/topology dependent
- The higher portion of the data link layer is often called the Logical Link Control (LLC)

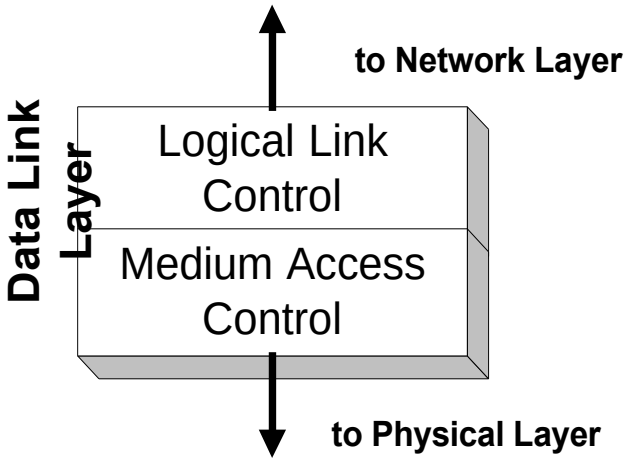
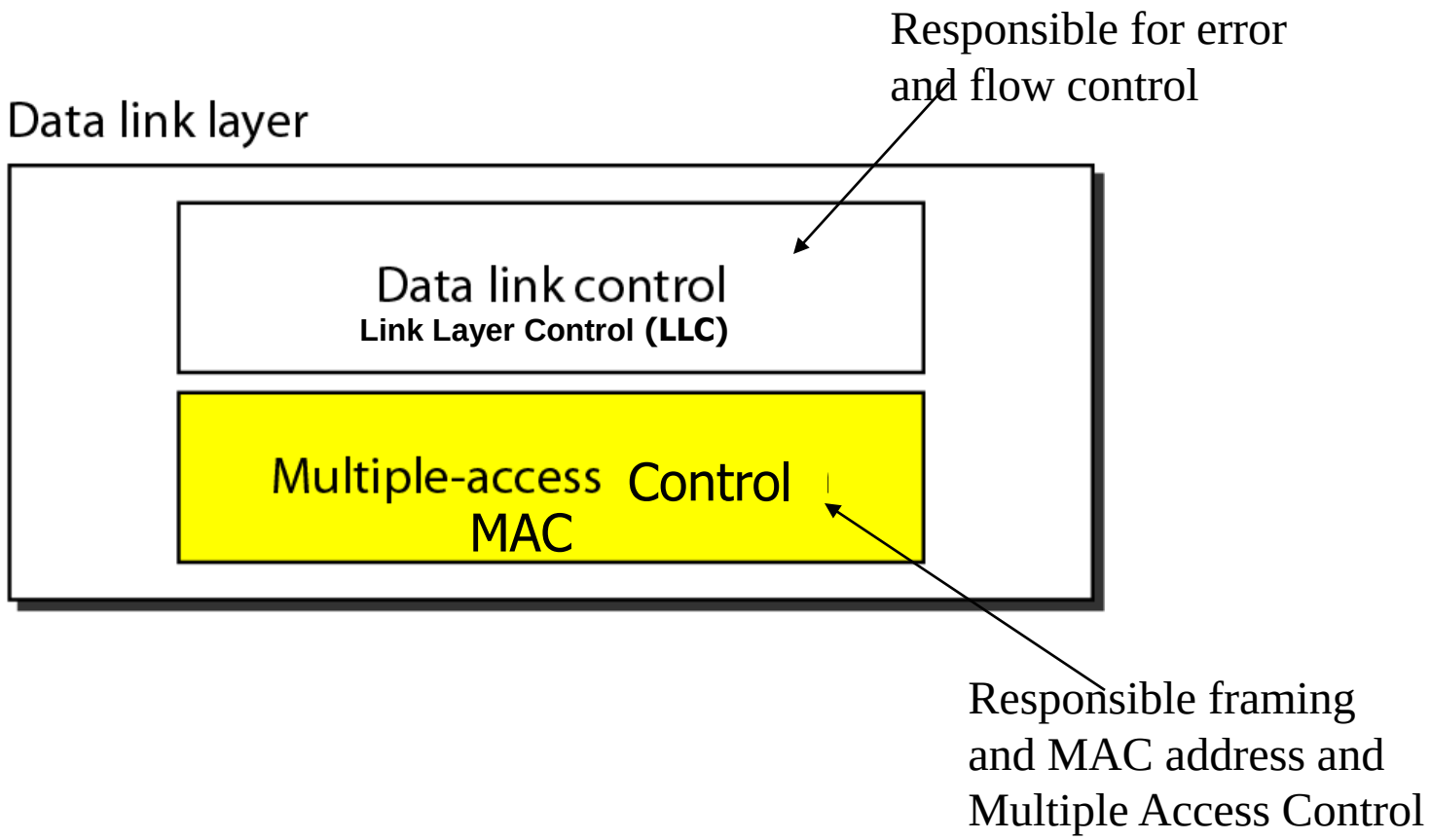


Figure 12.1 *Data link layer divided into two functionality-oriented sublayers*



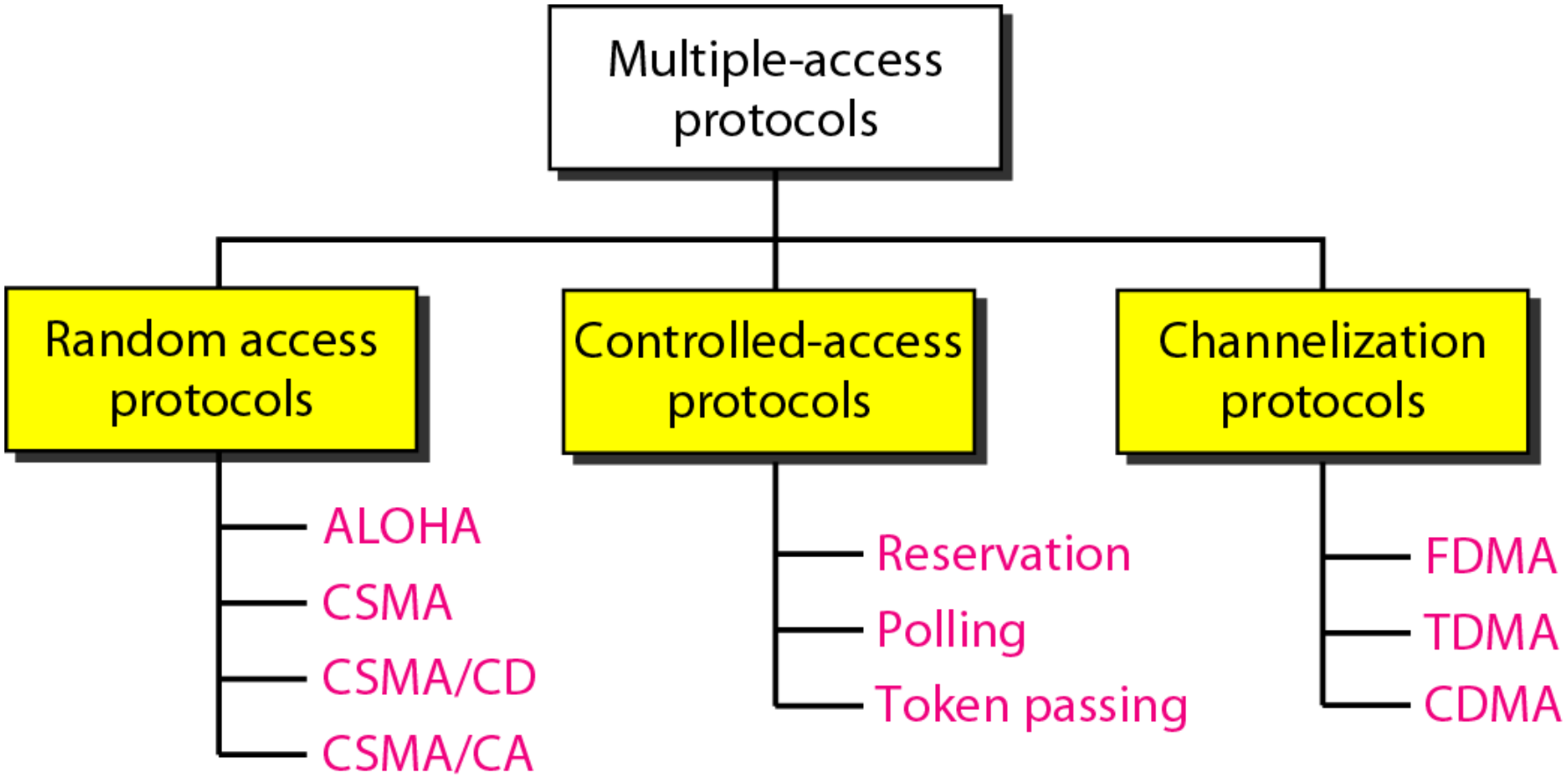
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Multiple Access

- **Problem**: When two or more nodes transmit at the same time, their frames will collide. All collide frames are lost and the link bandwidth is **wasted** during collision .
 - How to coordinate the access of multiple sending/receiving nodes to the shared link**???**
- **Solution**: We need a **protocol** to coordinate the transmission of the active nodes
- These protocols are called **Medium or Multiple Access Control (MAC) Protocols** belong to a **sublayer** of the data link layer called **MAC** (Medium Access Control)
- What is expected from Multiple Access Protocols:
 - Main task is to **minimize collisions** in order to **utilize the bandwidth** by:
 - Determining **when** a station can use the link (medium)
 - **what** a station should do when the link is **busy**
 - **what** the station should do when it is involved in **collision**

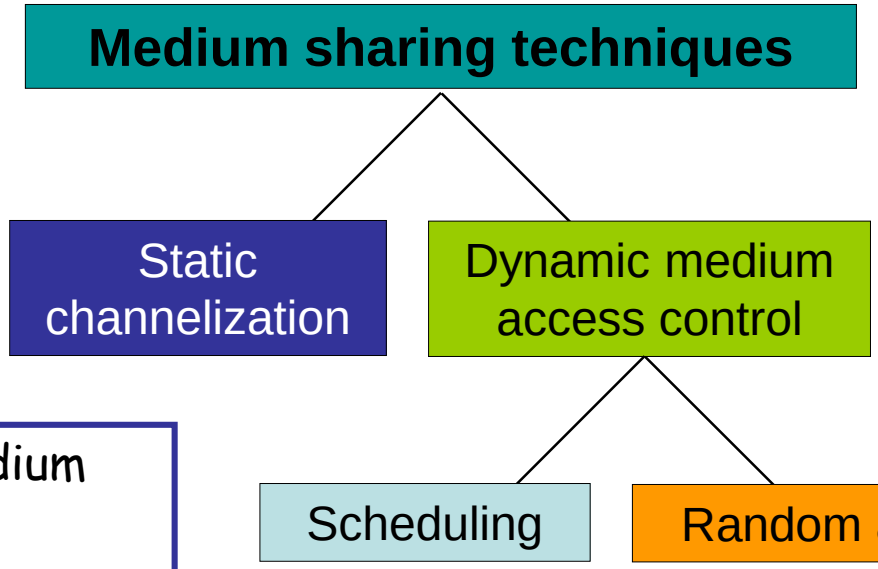
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Multiple-access protocols



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Approaches to Media Sharing



- Partition medium
- Dedicated allocation to users
- Satellite transmission
- Cellular Telephone

- Polling: take turns
- Request for slot in transmission schedule
- Token ring
- Wireless LANs

- Loose coordination
- Send, wait, retry if necessary
- Aloha
- Ethernet

Random Access

- **Random Access (or contention) Protocols:**
 - No station is superior to another station and none is assigned the control over another.
 - A station with a frame to be transmitted **can use the link directly based** on a procedure defined by the protocol to make a decision on whether or not to send.

- **ALOHA Protocols**
- Was designed for **wireless LAN** and can be used for **any shared medium**
- **Pure ALOHA** Protocol Description:
 - All frames from any station are of fixed length (**L bits**)
 - Stations transmit at equal **transmission time (*all stations produce frames with equal frame lengths*)**.
 - A station that has data **can transmit at any time**
 - **After transmitting a frame**, the sender **waits** for an **acknowledgment** for an amount of time (time out) equal to the **maximum round-trip propagation delay** = 2* t_{prop}(**see next slide**)

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Contention

- No control.
- Stations try to acquire the medium.
- Distributed in nature.
- Perform well for bursty traffic.
- Can get very inefficient under heavy load.

- If **no ACK** was received, sender assumes that the **frame or ACK** has been destroyed and **resends** that frame after it **waits for a *random* amount of time**

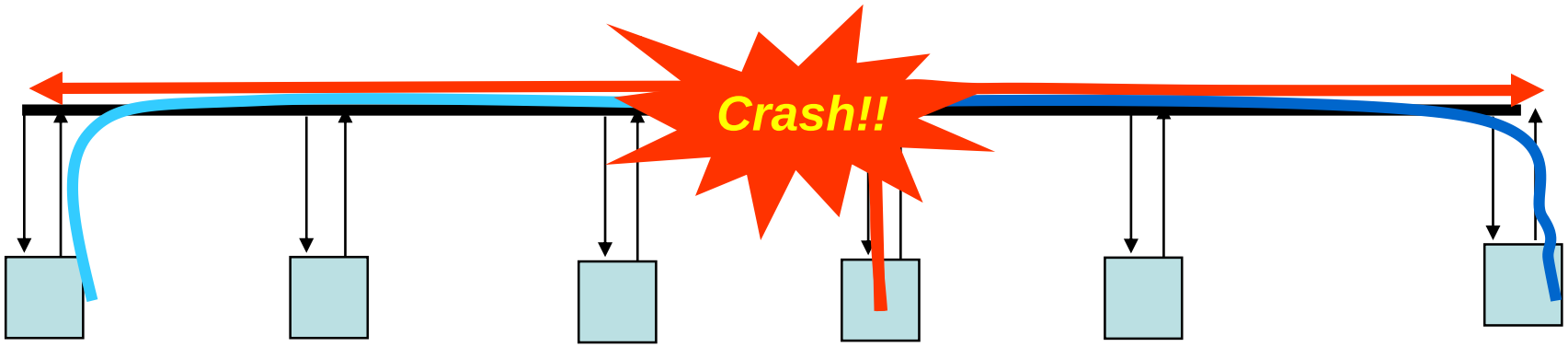
- **Channel utilization or efficiency or Throughput** is the **percentage** of the transmitted frames that arrive **successfully** (without collisions) **or** the **percentage** of the **channel bandwidth** that will be used for transmitting frames without collisions

- ALOHA Maximum channel utilization is **18%** (i.e, if the system produces **F frames/s**, then **0.18 * F** frames will arrive **successfully on average without the need of retransmission**).

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Random Access

Multitapped Bus



Transmit when ready

Transmissions can occur; need retransmission strategy

RANDOM ACCESS

In random access or contention methods, no station is superior to another station and none is assigned the control over another. No station permits , or does not permit, another station to send .At A each instance, a station that has data to send use a procedure defined by the protocol to make a decision on whether or not to send. This decision depends on the state of the medium(idle or busy)

Random access Methods:

- ALOHA
- Carrier Sense Multiple Access ; CSMA
- Carrier Sense Multiple Access with Collision Detection (CSMA/CD)
- Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)

RANDOM ACCESS

Each station has the right to the medium without being controlled by any other station.

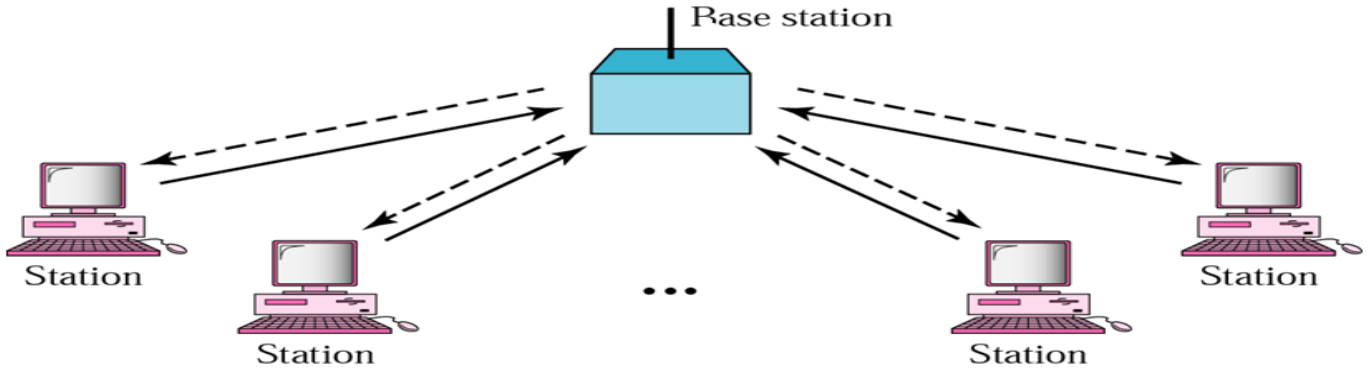
Two features gives the method its name:

- *There is no schedule time for a station to transmit: transmission is random among stations*
- *Stations compete with one another to access the medium Contention method.*

Collision: *an access conflict occurs when more than one station tries to send, as a result the frame will be either destroyed or modified.*

Pure ALOHA

- *The earliest random access method developed at the Univ. of Hawaii in the early 1970s*
- *Designed for a radio (wireless) LAN*
- *Simple method. Each station sends a frame whenever it has a frame to send.*
- *Since there is only one channel to share, there is the possibility of collision between frames from different stations.*

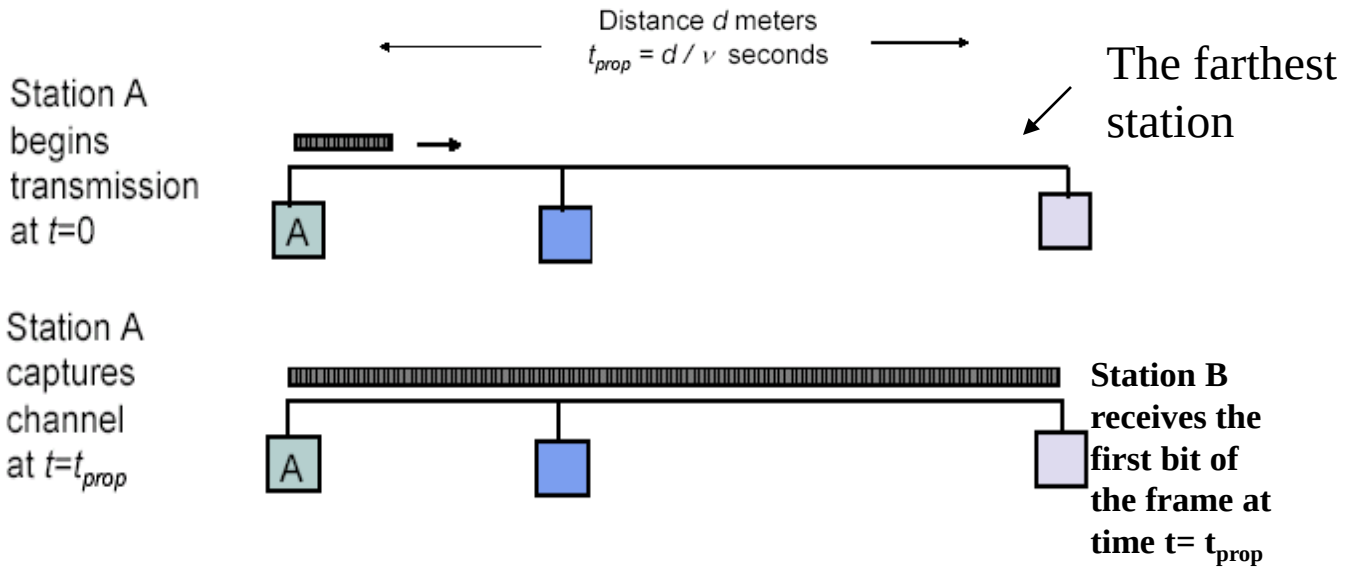


Pure ALOHA

- *Each station sends a frame whenever it has a frame to send.*
- *It relies on acknowledgments from the receiver.*
- *If the ACK dose not arrive after a time-out period, the station resend the frame.*

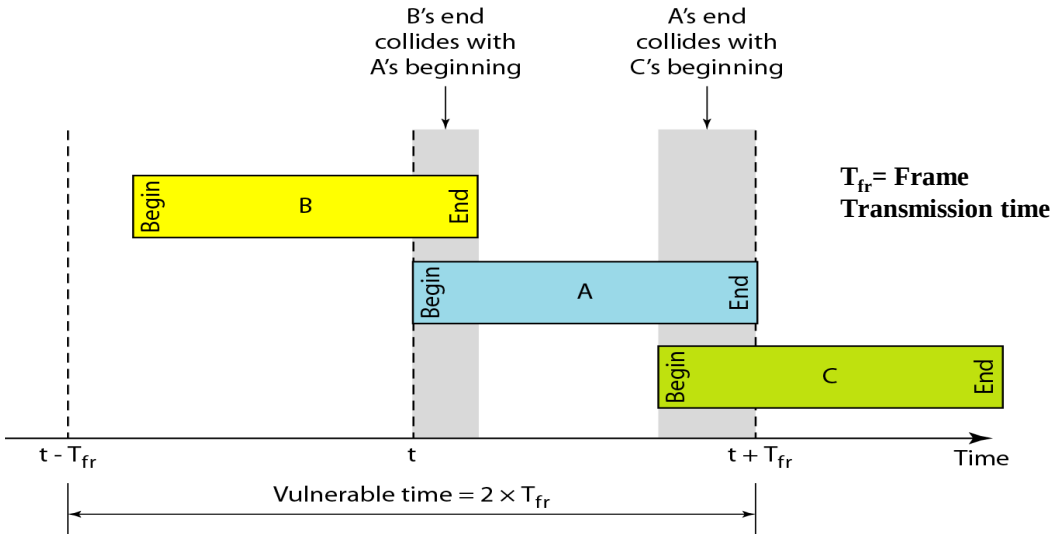
Maximum Propagation Delay

- **Maximum propagation delay**(t_{prop}): time it takes for a bit of a frame to travel between the **<u>two most widely</u>** separated stations.



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Critical time for pure ALOHA protocol

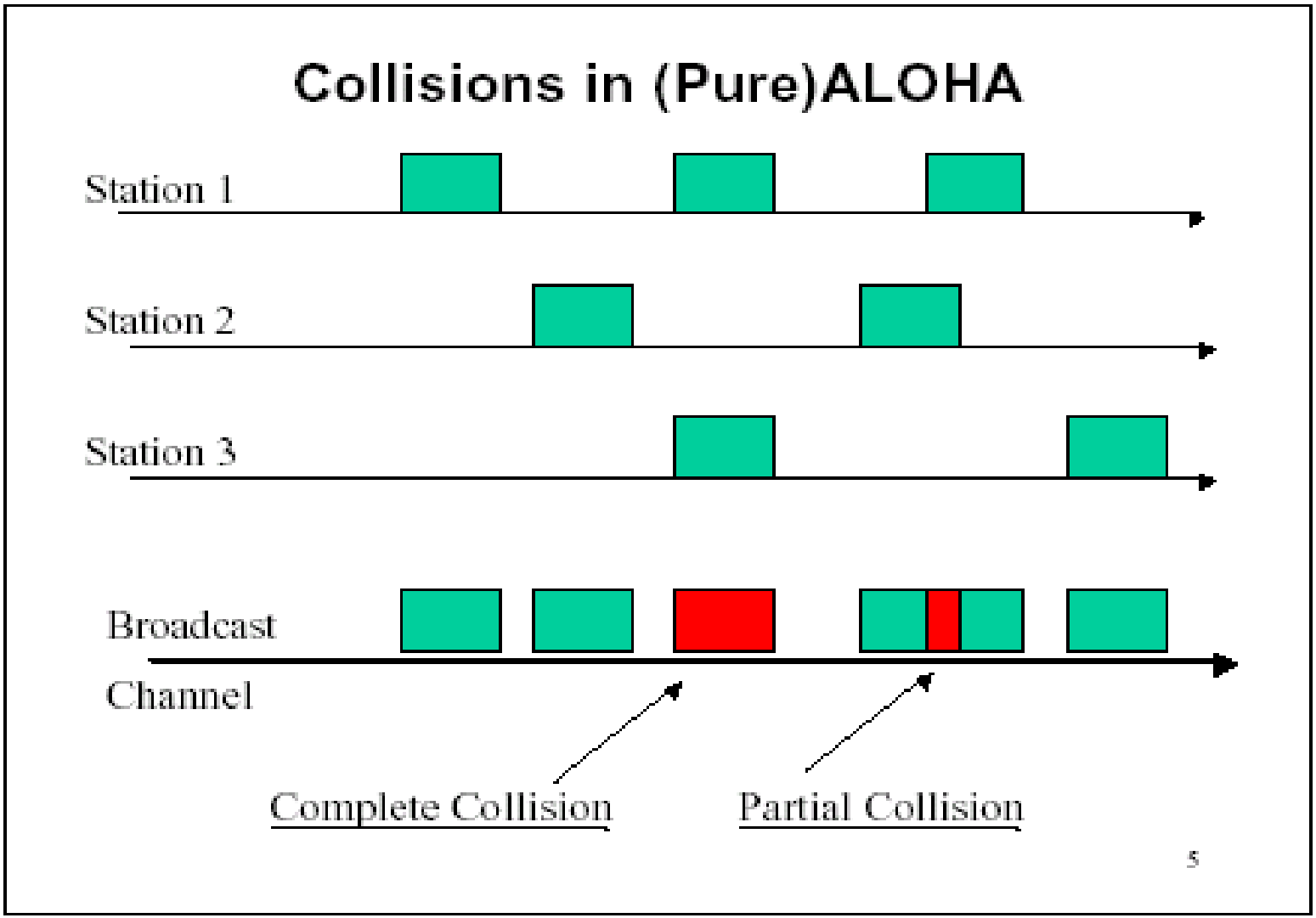


If the frame <u>transmission time</u> is T sec, then the vulnerable time is = 2 T sec.

This means no station should send during the T-sec before this station starts transmission and no station should start sending during the T-sec period that the current station is sending.

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Pure ALOHA



In pure ALOHA, frames are transmitted at completely arbitrary times.

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Note

The throughput (S) for pure ALOHA is $S = G \times e^{-2G}$.

The maximum throughput $S_{max} = 0.184$ when G= (1/2).

G = Average number of frames generated by the system (all stations) during one frame transmission time

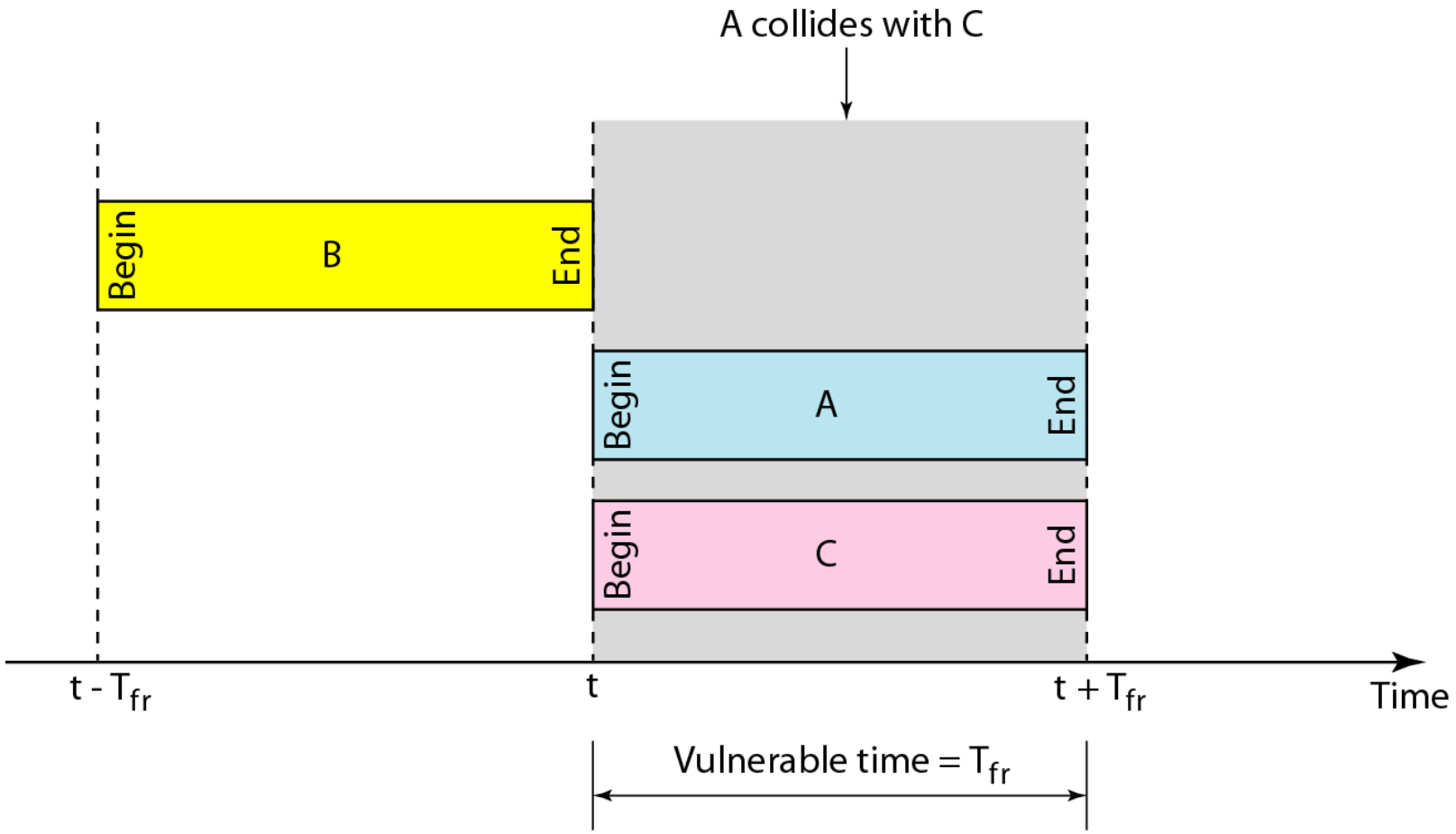
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Random Access – Slotted ALOHA

- Time is divided into slots equal to a **frame transmission time (T_{fr})**
- A station can transmit at the beginning of a slot only
- If a station misses the beginning of a slot, it has to wait until the beginning of the next time slot.
- **A central clock** or station informs all stations about the start of a each slot
- Maximum channel utilization is **37%**

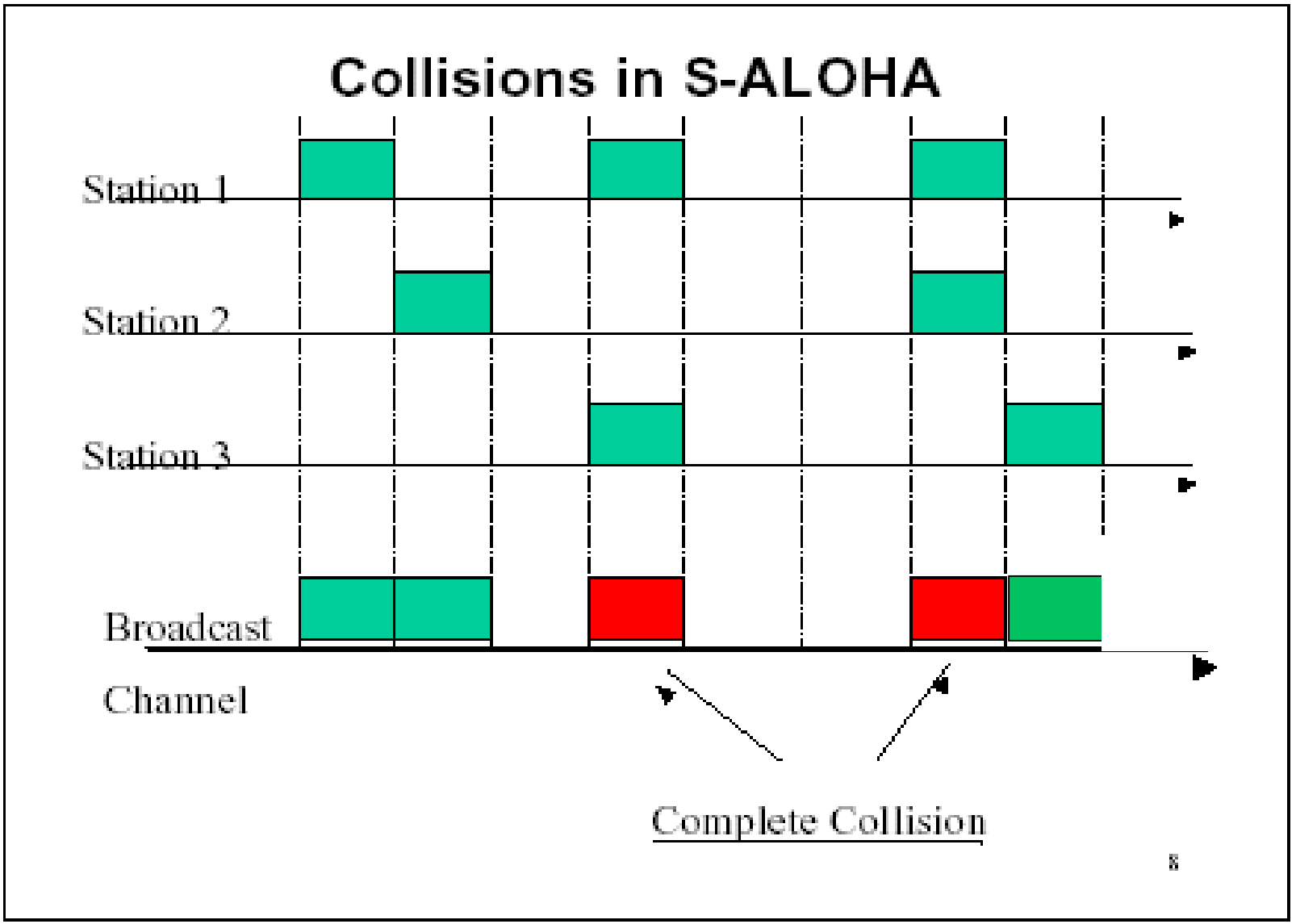
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In danger time for slotted ALOHA protocol



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Random Access – Slotted ALOHA



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Note

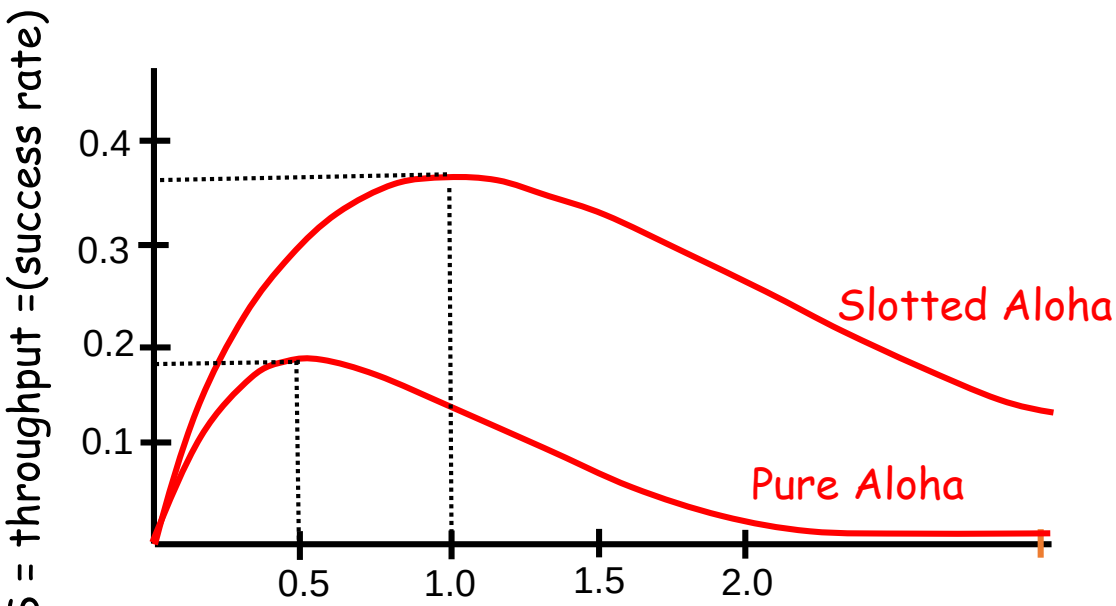
The throughput for slotted ALOHA is $S = G \times e^{-G}$.

The maximum throughput $S_{max} = 0.368$ when G = 1.

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Efficiency of Aloha



G = offered load rate= new frames+ retransmitted

= Total frames presented to the link per the transmission time of a single frame

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- Advantage of ALOHA protocols
 - A node that has frames to be transmitted can **transmit continuously** at the **full rate of channel (R bps)** if it is the only node with frames
 - Simple to be implemented
 - No master station is needed to control the medium
- Disadvantage
 - If (M) nodes want to transmit, many collisions can occur and the rate allocated for each node will **not be on average R/M bps**
 - This causes low channel utilization

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Carrier sense Multiple Access(CSMA)

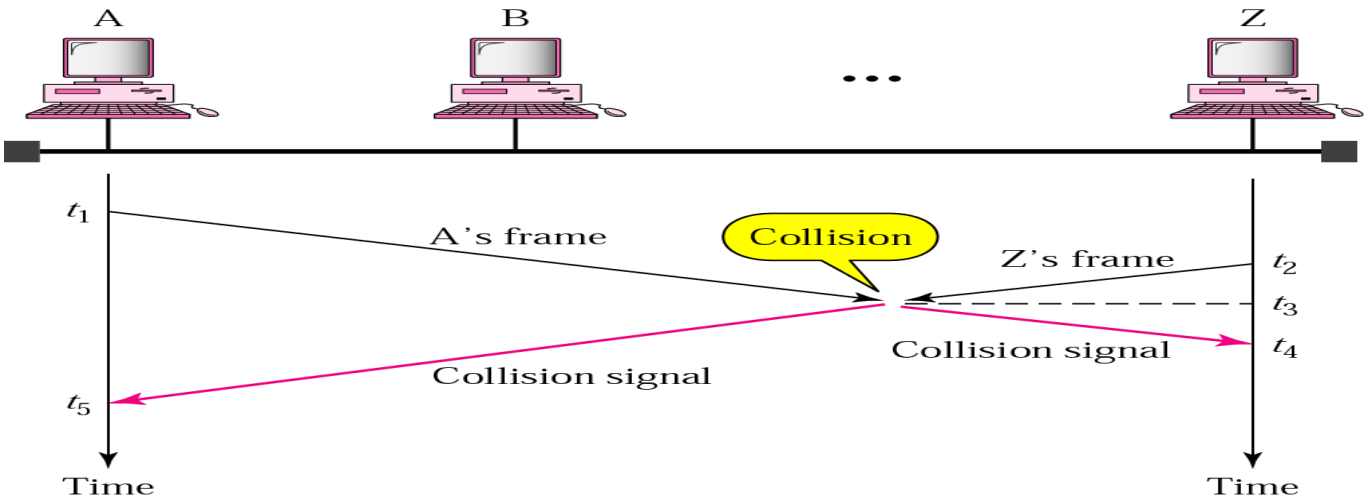
- *Sense the carrier before transmit : "listen before you talk"*
- *CSMA can reduce the possibility of collision, but it can not eliminate it because of the propagation delay (a station may sense the medium and find it idle, only because the first bit of a frame sent by another station has not been received)*

Carrier Sense Multiple Access collision detection (CSMA/CD)

- *Listen-while-talk ” protocol. A host listens even while it is transmitting, and if a collision is detected, stops transmitting*

Random Access – Carrier Sense Multiple Access (CSMA)

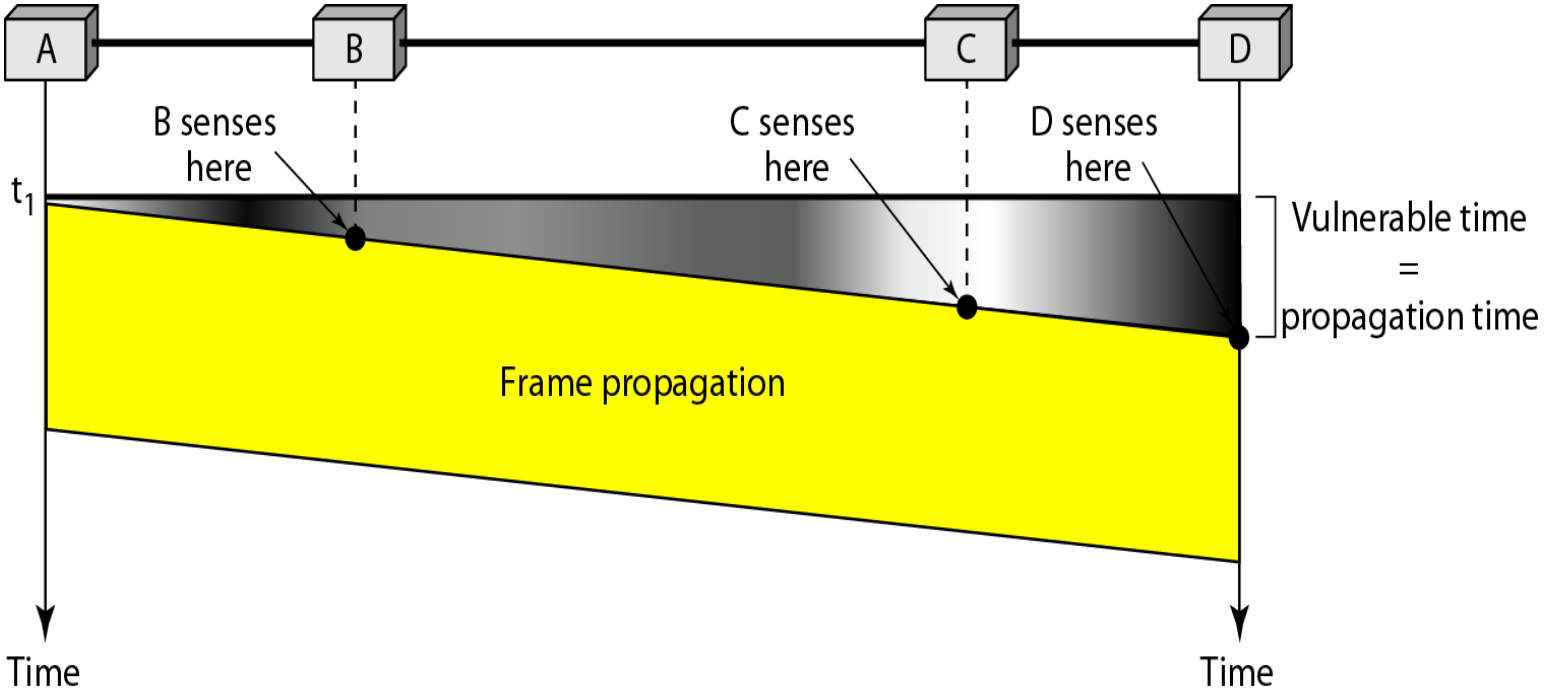
- To improve performance, avoid transmissions that are certain to cause collisions
- Based on the fact that in LAN propagation time is **very small**
- ➔ If a frame was sent by a station, All stations knows immediately so they can **wait before start sending**
 - ➔ A station with frames to be sent, should **sense the medium** for the presence of another transmission (carrier) before it starts its own transmission
- This can **reduce** the possibility of collision but it cannot eliminate it.
 - Collision can only happen when more than one station begin transmitting within a short time (the **propagation time** period)



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Random Access – Carrier Sense Multiple Access (CSMA)

- Vulnerable time for CSMA is the **maximum propagation time**
- The longer the propagation delay, the worse the performance of the protocol because of the above case.



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Types of CSMA Protocols

Different CSMA protocols that determine:

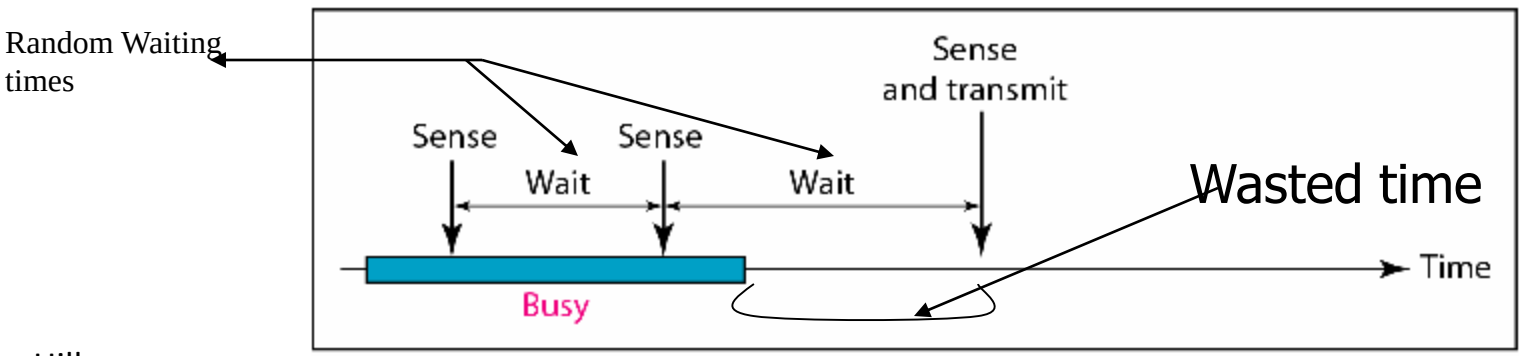
- What a station should do when the medium is **idle**?
- What a station should do when the medium is **busy**?

1. Non-Persistent CSMA
2. 1-Persistent CSMA
3. p-Persistent CSMA

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Nonpersistent CSMA

- A station with frames to be sent, should sense the medium
 1. If medium is idle, **transmit**; otherwise, go to 2
 2. If medium is busy, (**backoff**) wait a ***random* amount of time** and repeat **1**
- Non-persistent Stations are **deferential (respect others)**
- Performance:
 - Random delays reduces probability of collisions because two stations with data to be transmitted will wait for different amount of times.
 - Bandwidth is **wasted** if waiting time (backoff) is large because medium will remain idle following end of transmission even if one or more stations have frames to send

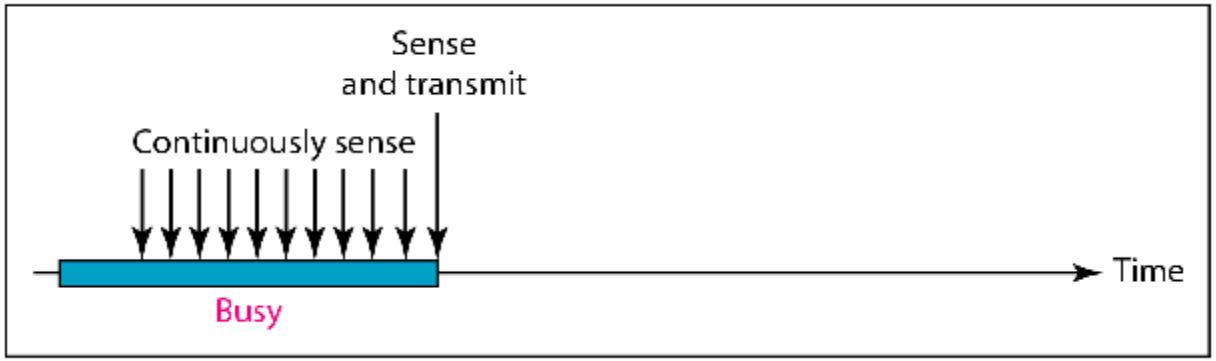


b. Nonpersistent

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1-persistent CSMA

- To avoid idle channel time, 1-persistent protocol used
- Station wishing to transmit listens to the medium:
 1. If medium idle, **transmit** immediately;
 2. If medium busy, **continuously listen** until medium becomes idle; then transmit immediately with probability 1
- Performance
 - 1-persistent stations are **selfish**
 - If two or more stations becomes ready at the same time, **collision guaranteed**



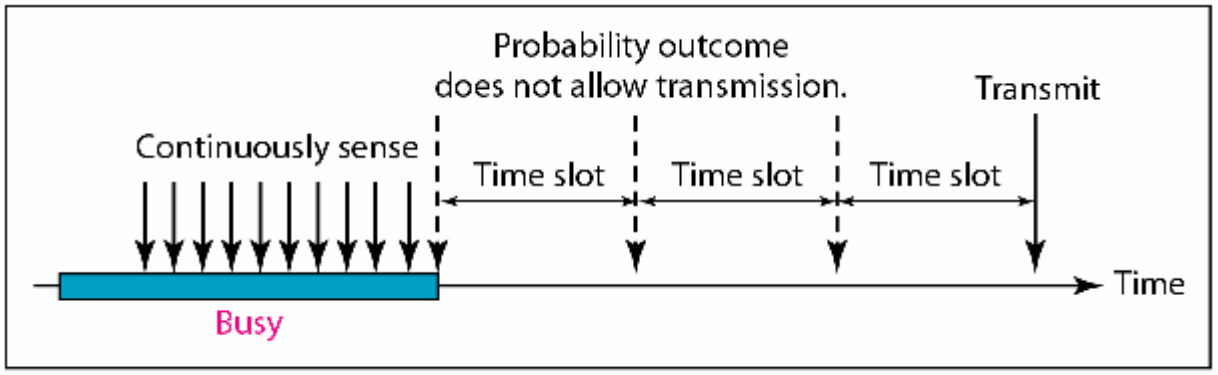
a. 1-persistent

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P-persistent CSMA

- Time is divided to slots where each Time unit (slot) typically equals **maximum propagation delay**
- Station wishing to transmit listens to the medium:

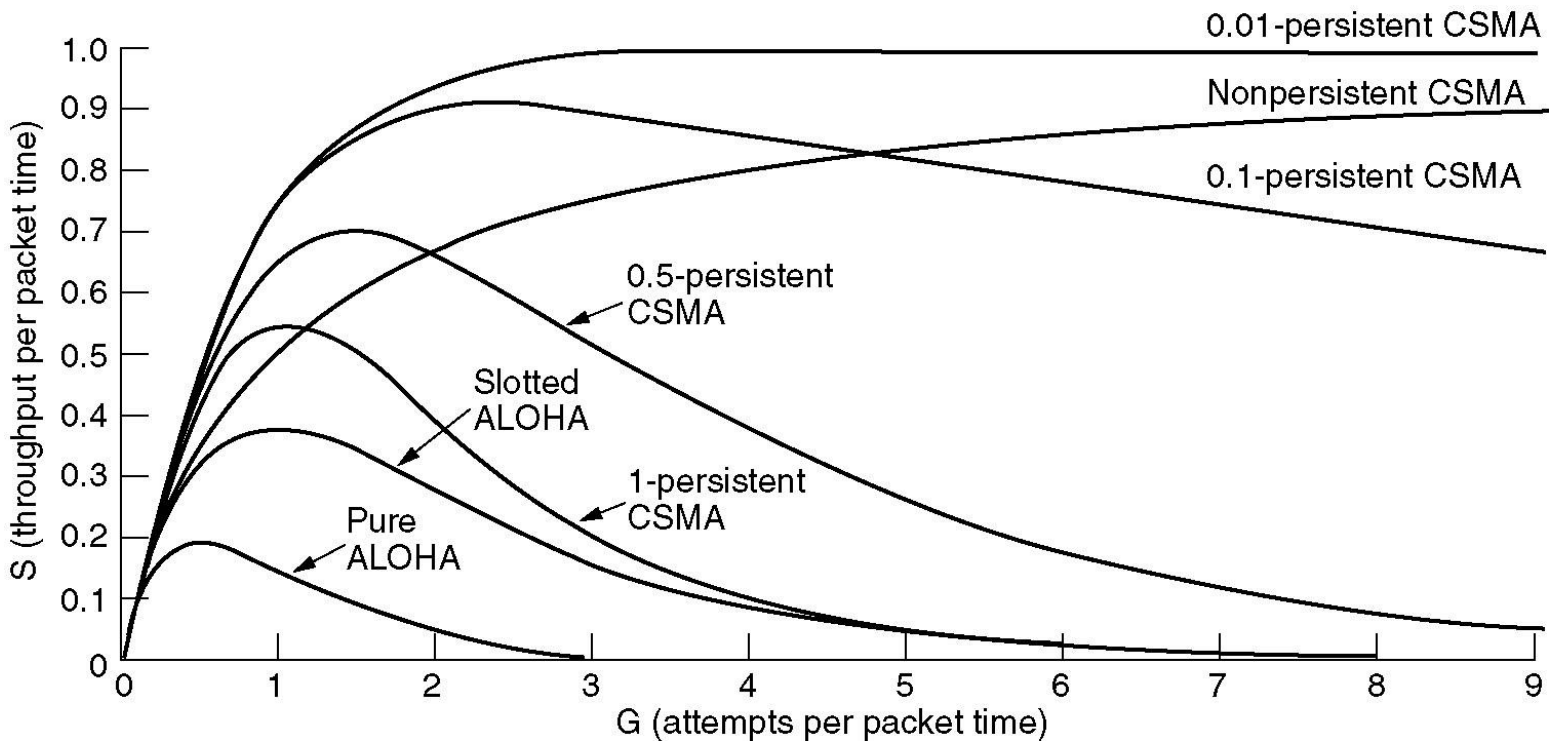
1. If medium idle,
 - transmit with probability (**p**), OR
 - wait **one time unit (slot)** with probability (**1 – p**), then repeat 1.
2. If medium busy, **continuously listen until idle** and repeat step **1**
3. Performance
 - Reduces the possibility of collisions like **nonpersistent**
 - Reduces channel idle time like **1-persistent**



c. p-persistent

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Persistent and Nonpersistent CSMA



Comparison of the channel utilization versus load for various random access protocols.

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CSMA/CD (Collision Detection)

- ***CSMA (all previous methods) has an inefficiency:***
 - If a collision has occurred, the channel is **unstable** until colliding packets have **been fully transmitted**
- ***CSMA/CD*** *(Carrier Sense Multiple Access with Collision Detection)* ***overcomes this as follows:***
 - While transmitting, the sender is **listening to medium** for collisions.
 - Sender **stops transmission** if collision has occurred **reducing channel wastage** .

CSMA/CD is Widely used for **bus topology LANs** (IEEE 802.3, Ethernet).

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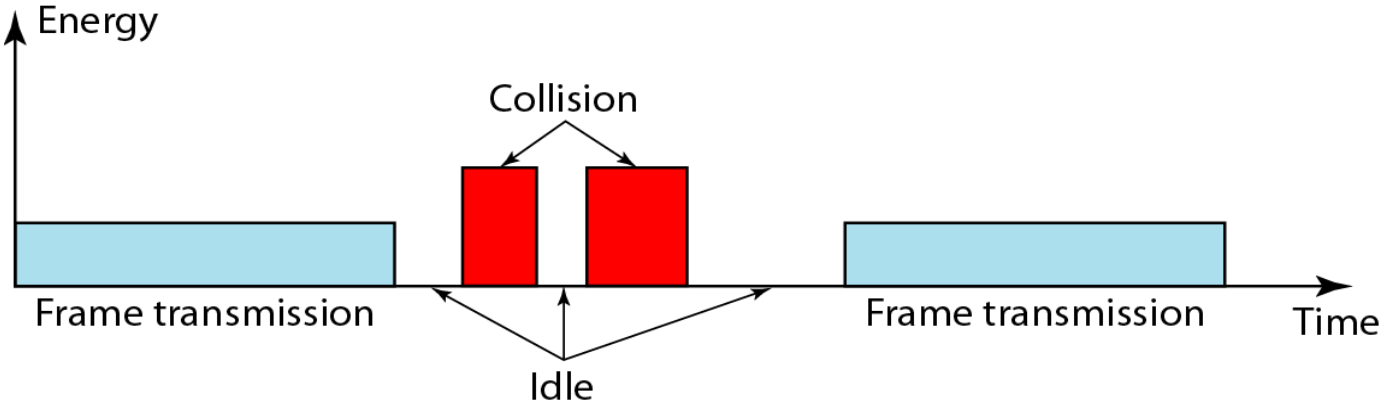
collision detection

How the station detects a collision?

- Detecting voltage level on the line
- Detecting energy level .

Energy in channel can have three values: zero, normal, **and abnormal.**

- at zero level, the channel is idle
- At the normal level, a station has successfully captured the channel and is sending its frame.
- At the abnormal level, there is a collision and the level of the energy twice the normal level.

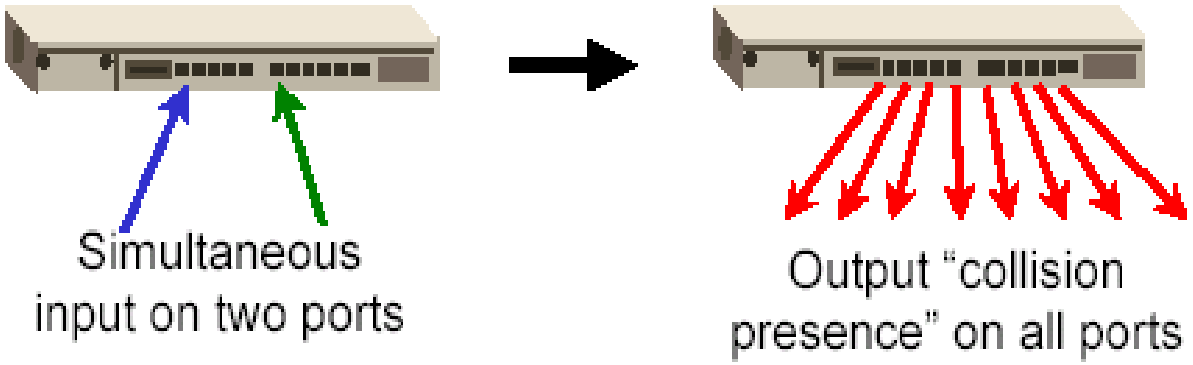


How does a node detect a collision?

Transceiver: **A node monitors the media while transmitting. If the observed power is more than transmitted power** of its own signal, it means collision occurred



Hub: **if input occurs simultaneously on two ports, it indicates a collision. Hub sends a collision presence signal on all ports.**



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CSMA/CD Protocol

- Use one of the CSMA persistence algorithm

(non-persistent, 1-persistent, p-persistent) for transmission

- If a collision is detected by a station during its transmission then it should do the following:
 - **Abort transmission** and
 - **Transmit** a ***jam signal*** (48 bit) to notify other stations of collision so that they will **discard the transmitted fra**me also to make sure that the collision signal will stay until detected by the furthest station
 - After sending the ***jam signal***, **backoff (wait) for a *random*** amount of time, then
 - Transmit the frame again

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Performance of Random Access Protocols

- Simple and easy to implement
- Decentralized (no central device that can fail and bring down the entire system)
- In low-traffic, packet transfer has low-delay
- However, limited throughput and in heavier traffic, packet delay has no limit.
- In some cases, a station may never have a chance to transfer its packet. (**unfair protocol**)
- A node that has frames to be transmitted can **transmit continuously** at the **full rate of channel (R)** if it is the **only node with frames**
- If (M) nodes want to transmit, many collisions can occur and the rate for each node will **not be on average R/M**

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13.2 Controlled Access or Scheduling

- Provides **in order access** to shared medium so that every station has chance to transfer (**fair protocol**)

- ***Eliminates*** collision completely
- **Three methods** for controlled access:
 - Reservation
 - Polling
 - Token Passing

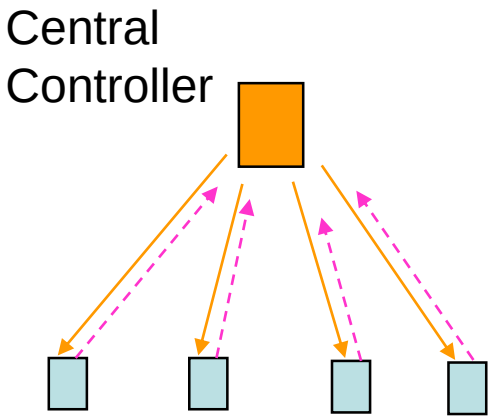
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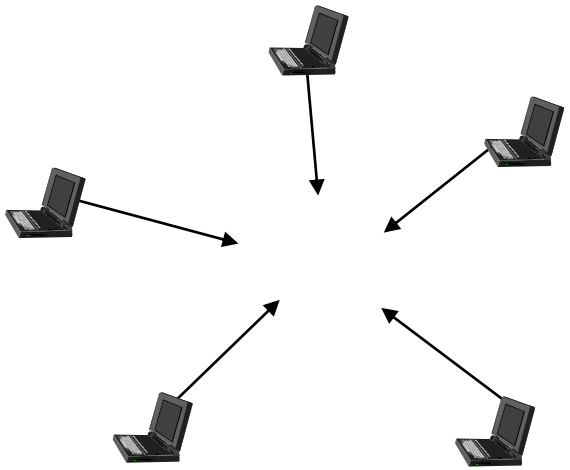
Reservation

- Time divided into slots.
- Station reserves slots in the future.
- Multiple slots for extended transmissions.
- Suited to stream traffic.

Reservations Systems

- *Centralized systems*: A central controller accepts requests from stations and issues grants to transmit
 - Frequency Division Duplex (FDD): Separate frequency bands for uplink & downlink
 - Time-Division Duplex (TDD): Uplink & downlink time-share the same channel
- *Distributed systems*: Stations implement a decentralized algorithm to determine transmission order





Reservation System Options

- Centralized or distributed system
 - *Centralized systems*: A central controller listens to reservation information, decides order of transmission, issues grants
 - *Distributed systems*: Each station determines its slot for transmission from the reservation information
- Single or Multiple Frames
 - *Single frame reservation*: Only one frame transmission can be reserved within a reservation cycle
 - *Multiple frame reservation*: More than one frame transmission can be reserved within a frame
- Channelized or Random Access Reservations
 - *Channelized (typically TDMA) reservation*: Reservation messages from different stations are multiplexed without any risk of collision
 - *Random access reservation*: Each station transmits its reservation message randomly until the message goes through

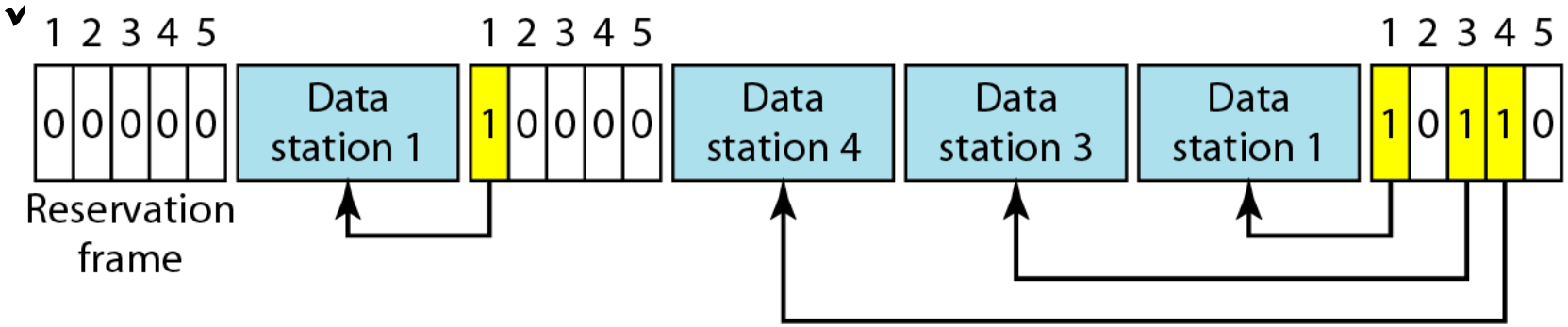
Reservation access method

A station needs to make a reservation before sending data.

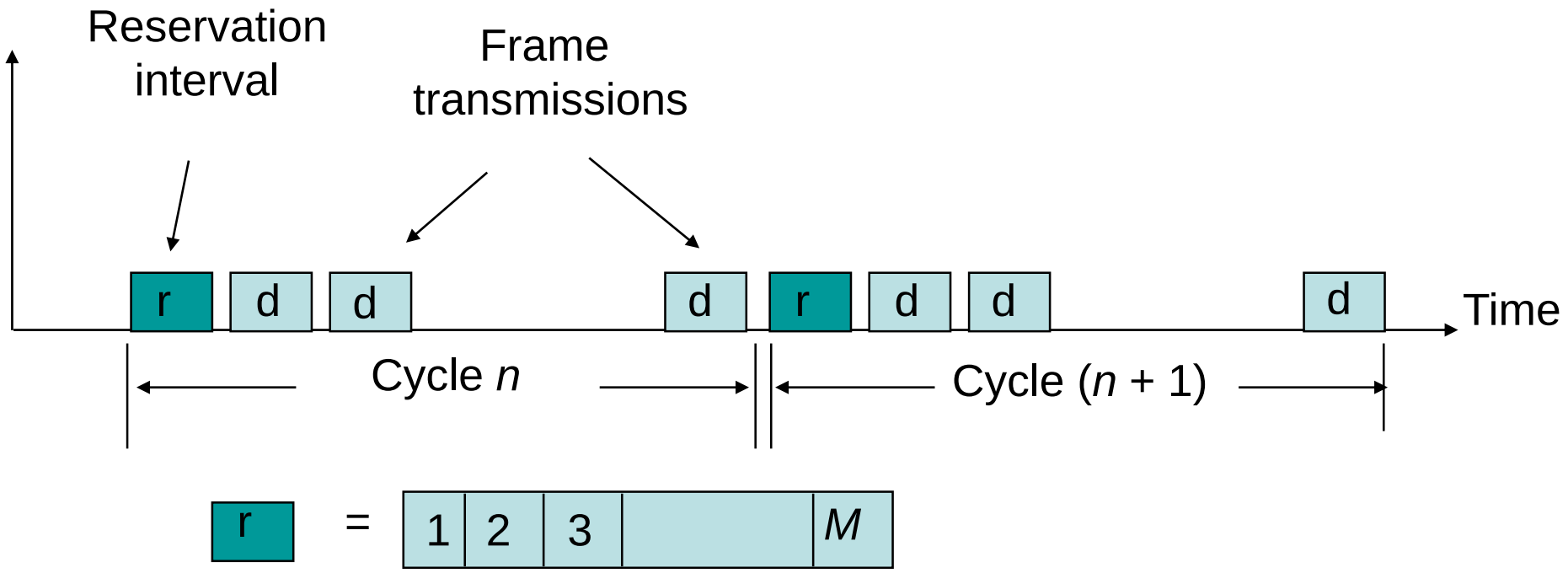
- Transmissions are organized into variable length cycles
- Each cycle begins with a reservation interval that consists of (N) minislots. One minislot for each of the N stations

Time is divided into intervals

- ✓ A reservation frame proceeds each time interval
- ✓ Number of stations and number of mini-slots in the reservation frame are equal.
- ✓ Each time slot belongs to a particular station.



Reservation Systems



- Transmissions organized into cycles
- Cycle: reservation interval + frame transmissions
- Reservation interval has a minislot for ***each*** station to request reservations for frame transmissions

2- Polling

- Stations take turns accessing the medium
- Two models: **Centralized** and **distributed** polling
- **Centralized polling**
 - One device is assigned as **primary station** and the others as **secondary stations**
 - All data exchanges are done through the **primary**
 - When **the primary has a frame to send** it sends a **select** frame that includes the address of the intended secondary
 - When **the primary is ready to receive** data it send a **Poll** frame for each device to ask if it has data to send or not. If yes, **data** will be transmitted otherwise **NAK** is sent.
- **Distributed polling**
 - **No primary and secondary**
 - Stations have a **known polling order** list which is made based on some protocol
 - **station with the highest priority** will have the access right first, then it passes the access right to the **next station (it will send a pulling message to the next station in the pulling list)**, which will passes the access right to the following next station, …

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Polling access method-Centralized polling

Devices are designated as a Primary station and secondary station.

All data exchange must go through the primary station

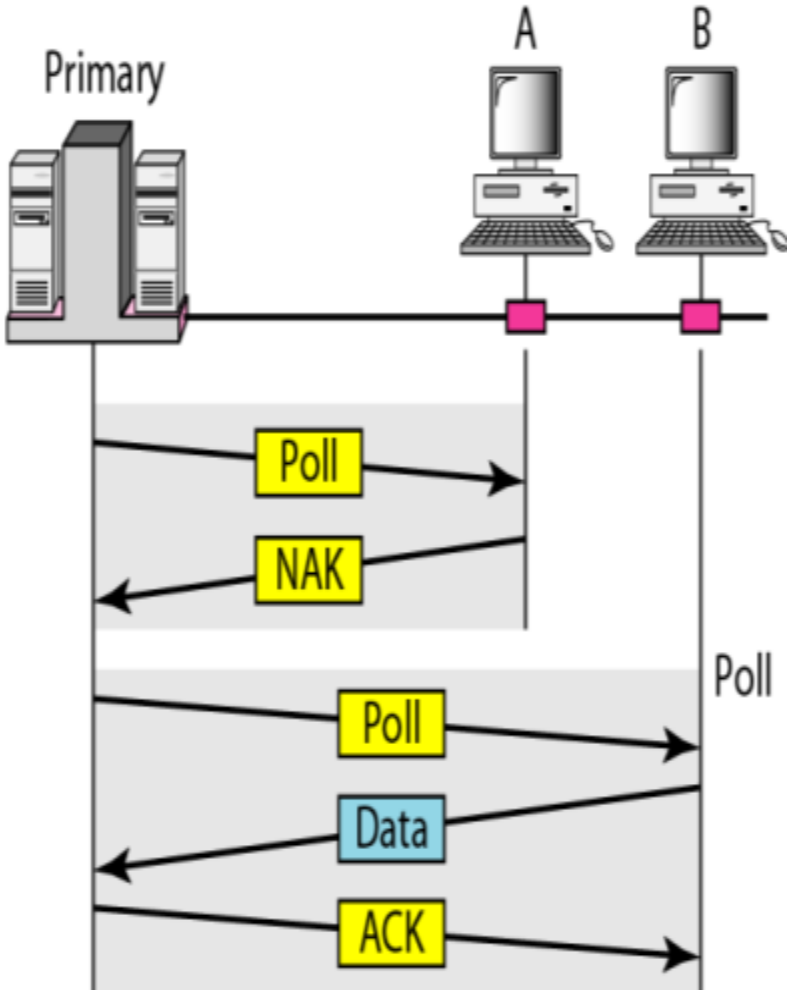
Primary station controls the link and initiates the session; the secondary station follow its instructions.

Two functions: polls and select

Poll: If the primary wants to receive data, it asks the secondary if they have anything to send.

Select: if the primary wants to send data, it tells the secondary to get ready to receive data

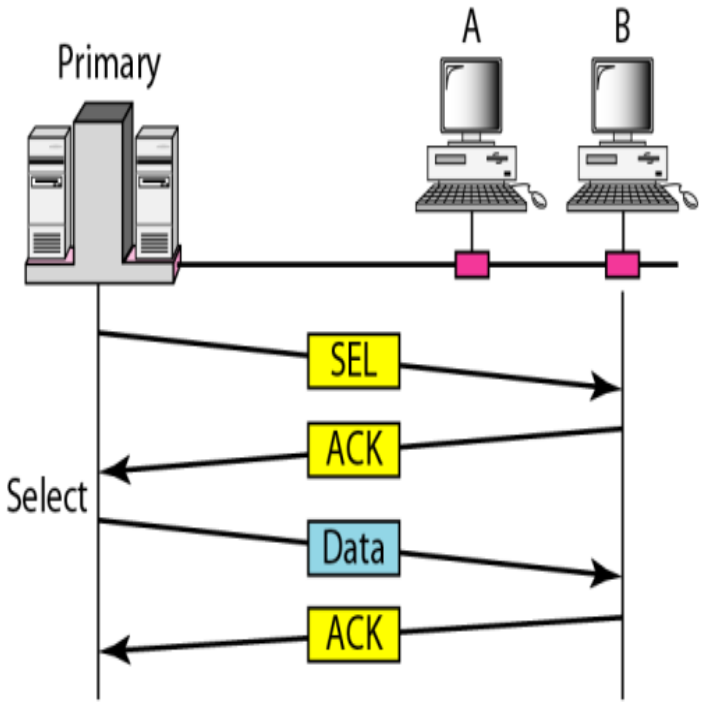
Polling access method



When the primary is ready to receive data, it must ask (Poll) each device in turn if it has anything to send.

- When the first secondary is approached, it responds either with a NAK frame if it has nothing to send or with data if it does.
- If the response is NAK, the primary polls the next secondary.
- If it receives data, it sends ACK frame.

Polling access method



The select function is used when the primary has frames to send.

- The primary creates and transmits a select (SEL) frame.
- SEL alerts the secondary to the upcoming transmission
- The primary waits for ACK to send the data

Token Passing method -Distributed polling

In the token-passing, the stations are organized in a logical ring.

•For each station there is a predecessor and a successor
•predecessor is the station which is logically before the station in the ring
•The successor is the station which is logically after the station in the ring
•The current station is the one that accessing the channel now.

How is The right to access channel passed from one station to another?

Token Passing method

Station is authorized to send data when it receives a special frame called a token

- Stations are arranged around a ring.
- When no data are being sent, a token circulates the ring.
- If a station needs to send data, it waits for the token.
- The station captures the token and sends one or more frames (as long as it has frames to send or the allocated time has not expired), and finally it releases the token to be used by next station (successor).
- The maximum time any station can hold the token is limited.
- Since there is only one token, only one station transmits at a time, and collisions never occur.

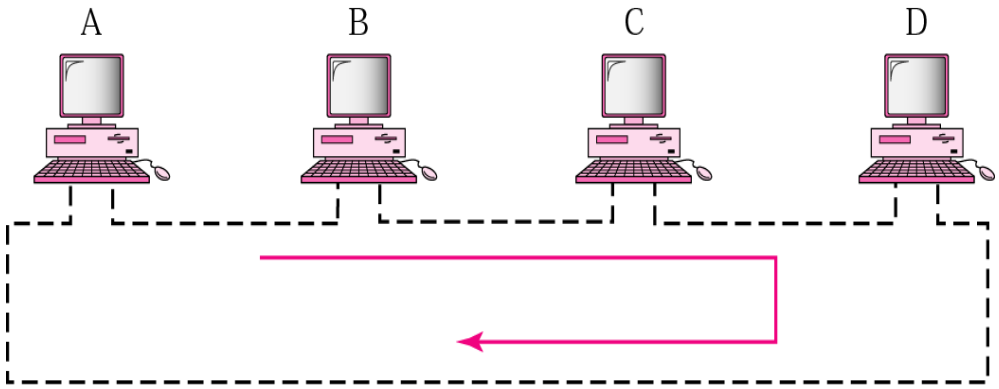
Token Passing method

Token management is needed for this access method:

- Stations must be limited in the time they can have possession of the token
- the token must be monitored to ensure it has not been lost or destroyed(if the station that is holding the token fails, the token will disappear from the network)

3- Token-Passing network

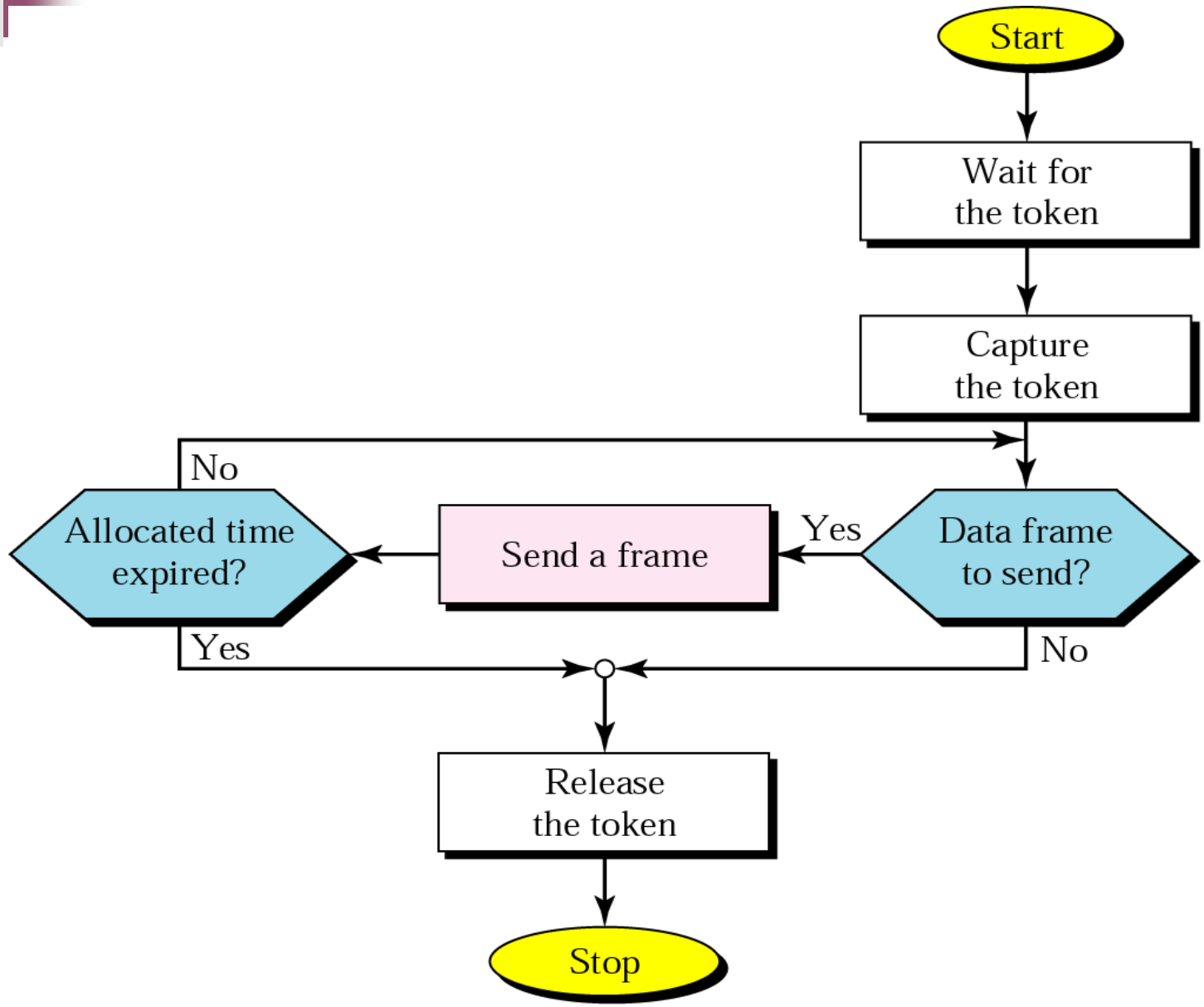
Implements Distributed Polling System



- **Station Interface is in two states**:
 - **Listen state**: Listen to the arriving bits and check the destination address to see if it is its own address. If yes the frame is copied to the station otherwise it is passed through the output port to the next station.
 - **Transmit state**: station captures a special frame called **free token** and transmits its frames. **Sending** station is responsible for **reinserting** the free token into the ring medium and for **removing** the transmitted frame from the medium.

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Figure 13.13 Token-passing procedure



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12-3 CHANNELIZATION

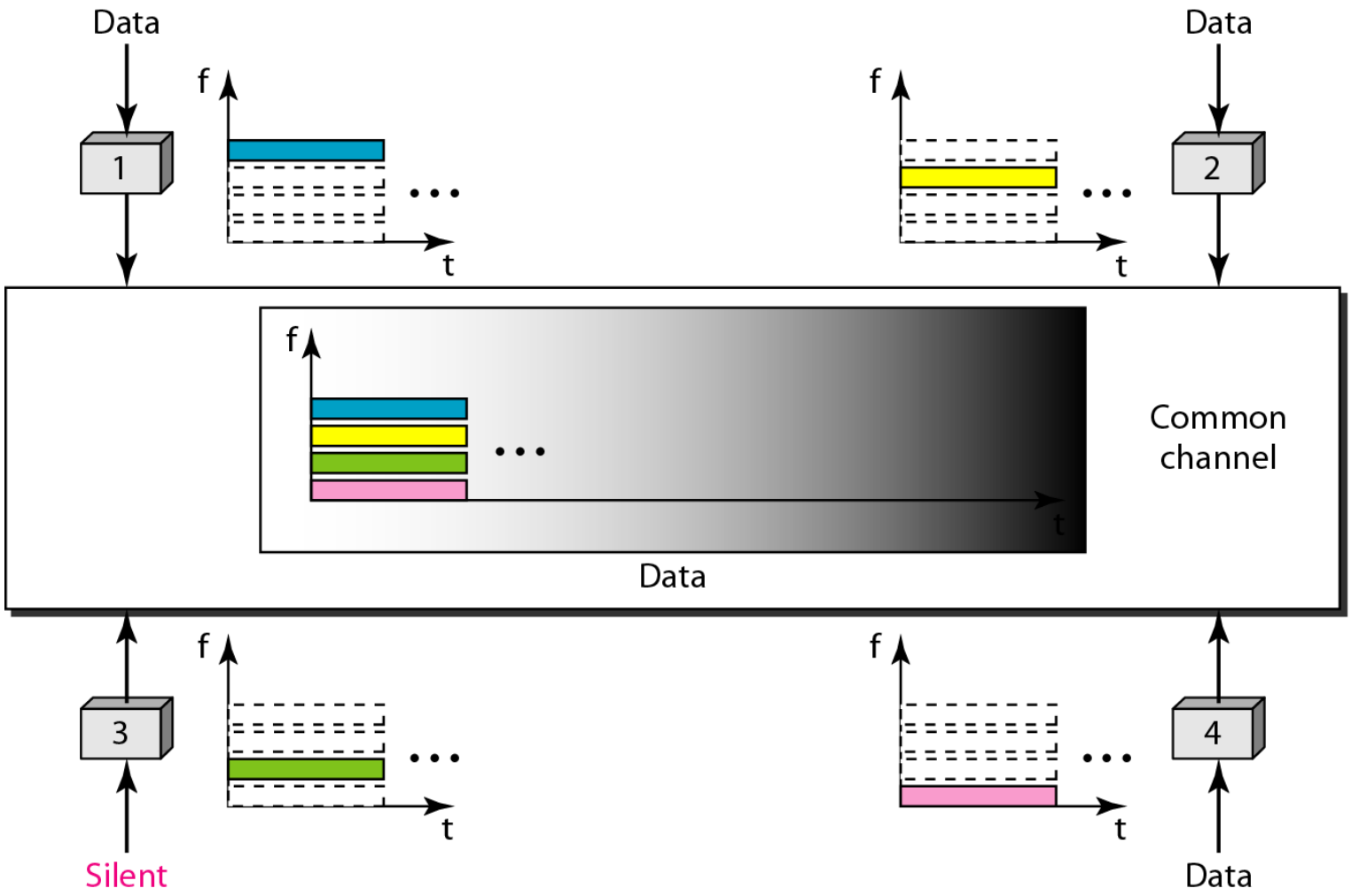
***Channelization** is a multiple-access method in which the available bandwidth of a link is shared in time, frequency, or through code, between different stations. In this section, we discuss three channelization protocols.*

Topics discussed in this section:

Frequency-Division Multiple Access (FDMA)
Time-Division Multiple Access (TDMA)
Code-Division Multiple Access (CDMA)

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Figure 12.21 *Frequency-division multiple access (FDMA)*



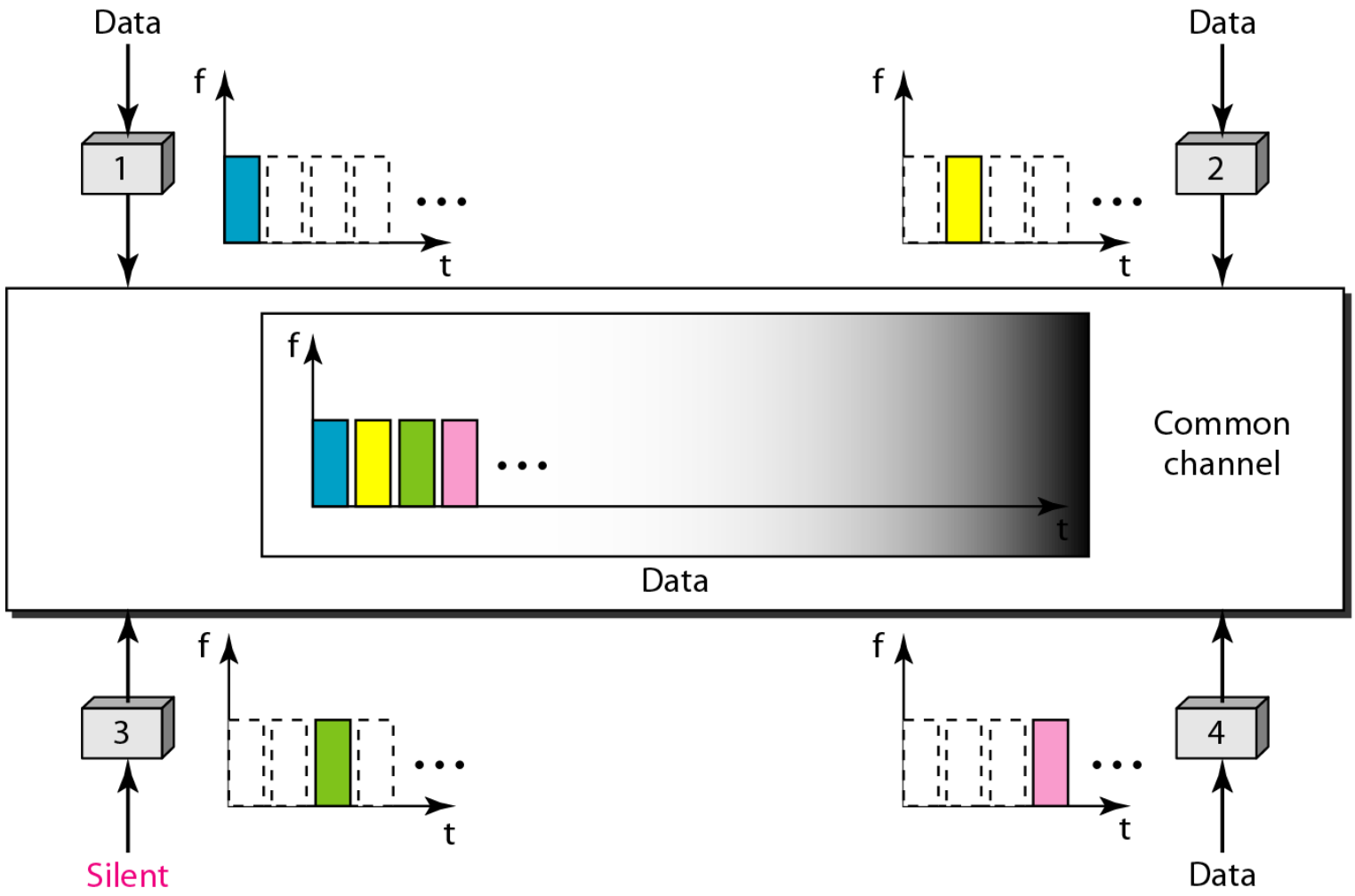
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12-3 CHANNELIZATION - FDMA

- **FDMA:** Frequency Division Multiple Access:
 - Transmission medium is divided into **M** separate frequency bands
 - Each station transmits **continuously** on the assigned band at an average rate of **R/M**
 - A node is **limited** to an average rate equal **R/M** (where M is number of nodes) even when it is **the only node with frame** to be sent

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Figure 12.22 *Time-division multiple access (TDMA)*



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12-3 CHANNELIZATION - TDMA

- **TDMA: Time Division Multiple Access**
 - The entire bandwidth capacity is a **single channel** with its capacity shared **in time** between **M** stations
 - A node must **always wait for its turn** until its slot time arrives even when it is the **only node** with frames to send
 - A node is limited to an average rate equal **R/M** (where M is number of nodes) even when it is the only node with frame to be sent

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12-3 CHANNELIZATION - CDMA

- **CDMA: Code Division Multiple Access**
 - In CDMA, **one channel** carries all transmissions **simultaneously**
 - Each station codes its data signal by a specific codes before transmission
 - The stations receivers use these codes to recover the data for the desired station

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Comparison of MAC approaches

- Aloha & Slotted Aloha
 - Simple & quick transfer at very low load
 - Accommodates large number of low-traffic bursty users.
- CSMA-CD
 - Quick transfer and high efficiency.
 - Can accommodate large number of bursty users
- Reservation
 - On-demand transmission of bursty or steady streams
- Polling
 - Provides fairness through regular access opportunities.